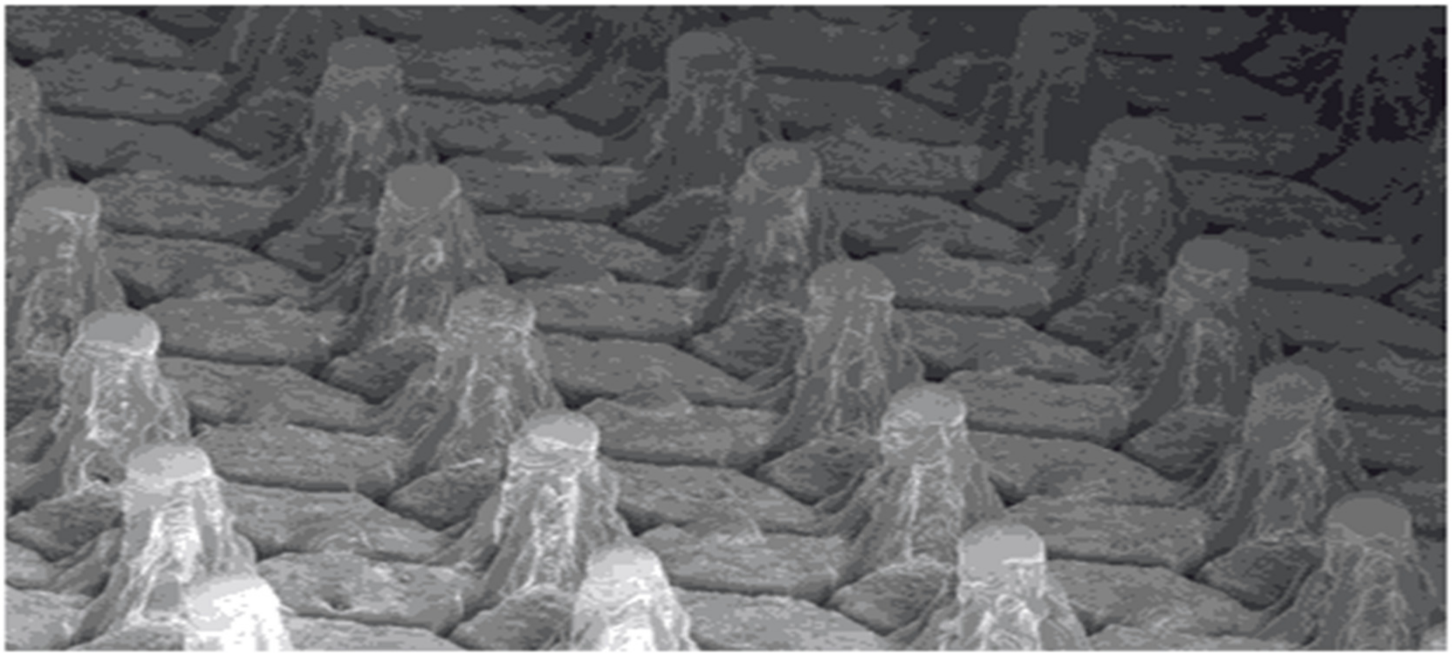
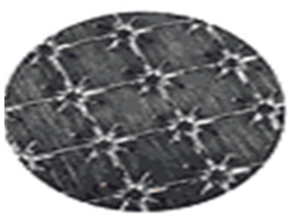
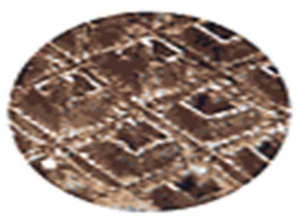
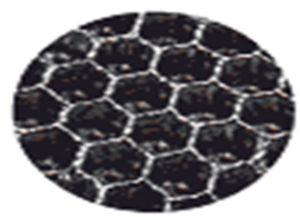
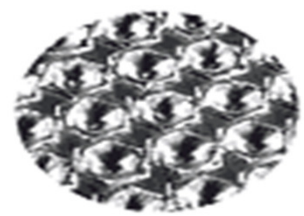
Laser Surface Texturing











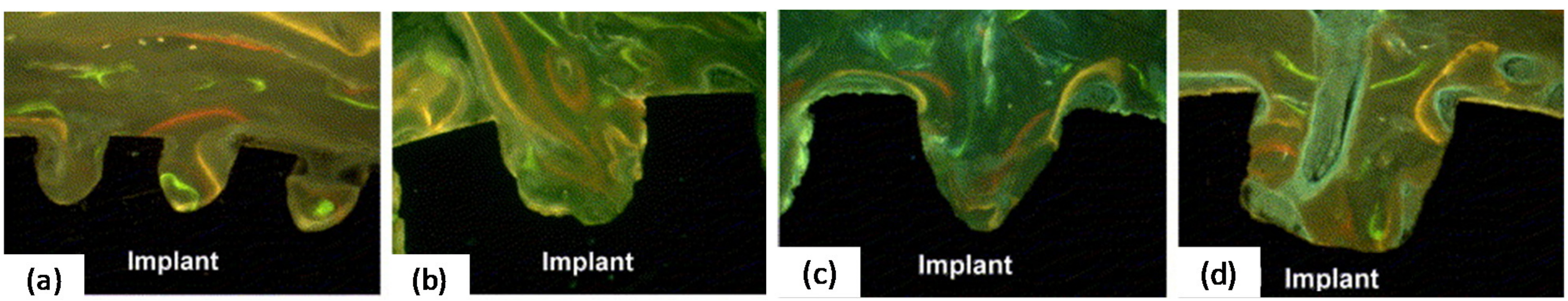
Laser Surface Texturing

- Laser surface texturing has emerged as a viable means of enhancing tribological performance and biomedical applications in recent years.
- The laser is extremely fast , clean to environment and provides excellent control on shape and size of microstructures.

- Several applications will be shown to benefit from LST which are dynamic sealing, magnetic recording, internal combustion engines and biocompatible surfaces.

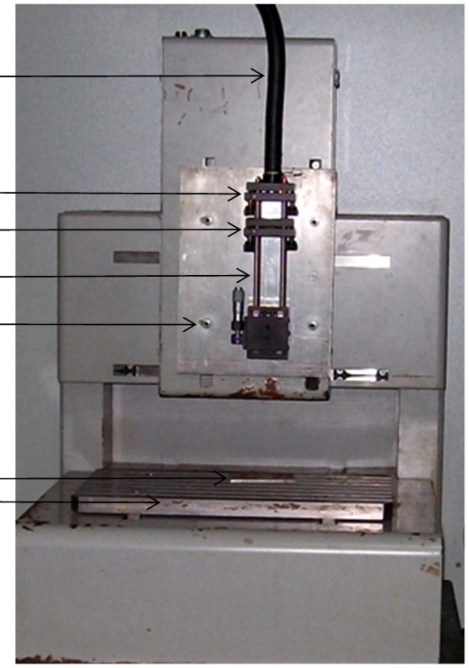
Biomedical Applications for Laser Texturing

- Wettability for better interaction with biological liquids
- Rougher Ti surfaces provide increased osseointegration
- Laser textured surfaces promote better contact guidance (cell alignment) as compared to sand blasted surfaces



Experimental Setup

100 W Yb-doped Fiber Laser
SPI Laser SP-100C-0020
Wavelength: 1064 nm
Frequency: CW - 100 kHz
Positioning stages: MikroTools
Resolution/Accuracy : 0.1 µm and ± 1 mm



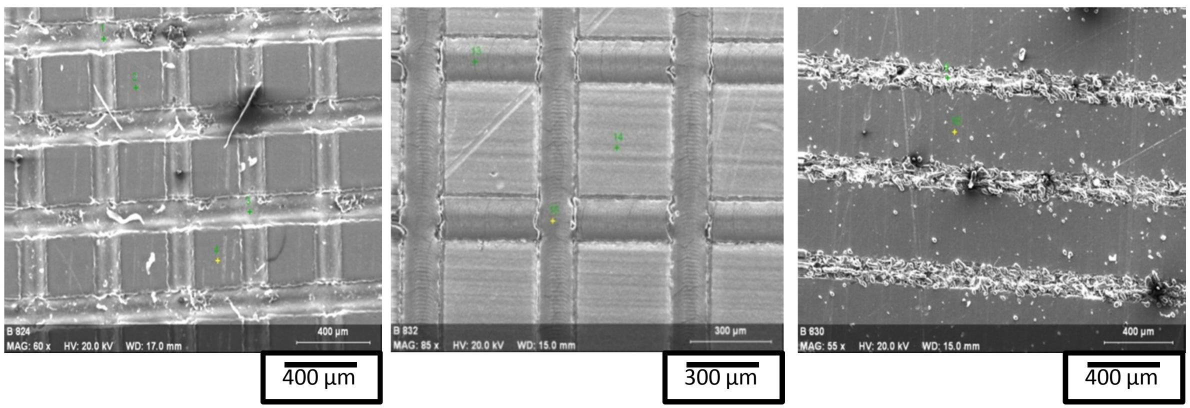
Indian Patent Application No 442/MUM/2011 Filed on 17 February 2011

Method and device for generating laser beam of variable intensity distribution and variable spot size

Creation of Textured Surfaces

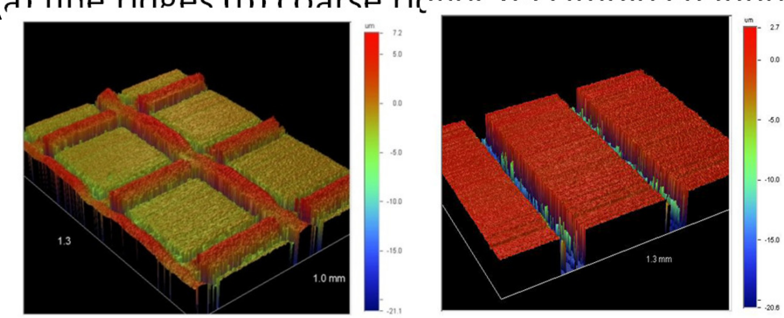
- Parametric studies for simple channels
- Optimal parameters used for creation of textures

  (scan velocity 700 mm/min, Laser power 70 W, Frequency 5 KHz, pulse width 0.1 ms, single pass)



(a) (b) (c)

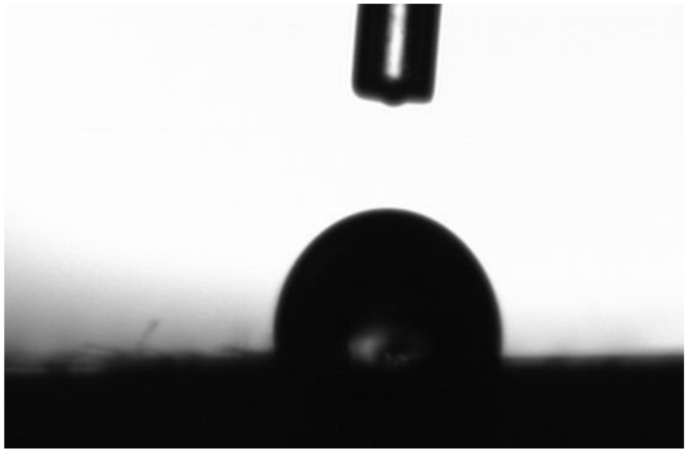
SEM image of :(a) fine ridges (b) coarse ridges (c) simple channels



(a) (b)

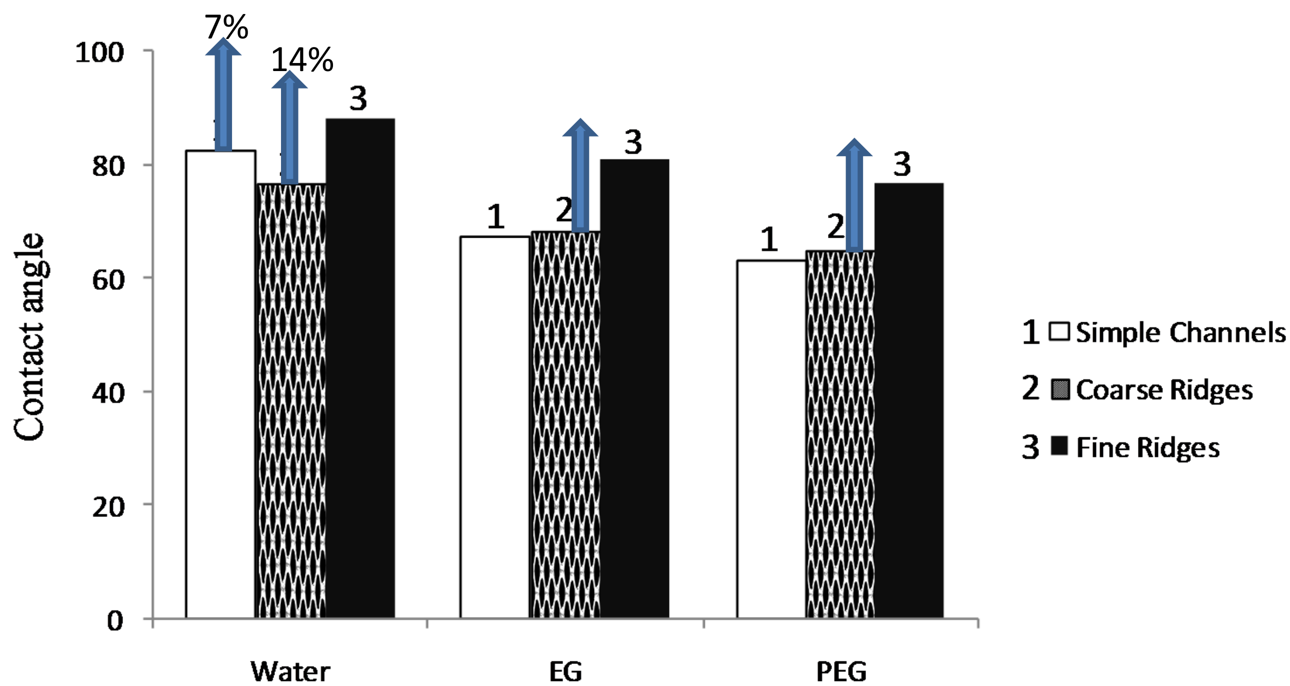
Wettability Characterization

- Wettability tests could capture the functional response of the surface
- Wettability tests with different fluids:
  - Water
  - Ethylene Glycol (EG)
  - Polyethylene Glycol (PEG)
- Three different surfaces:
  - Baseline untreated
  - Sand blasted
  - Laser textured

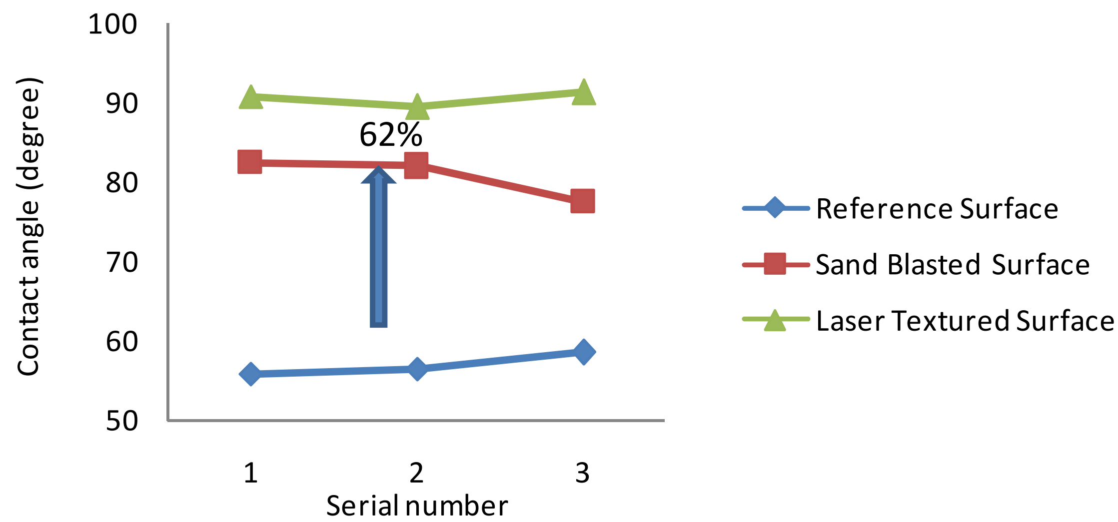


Contact angle on laser treated surface

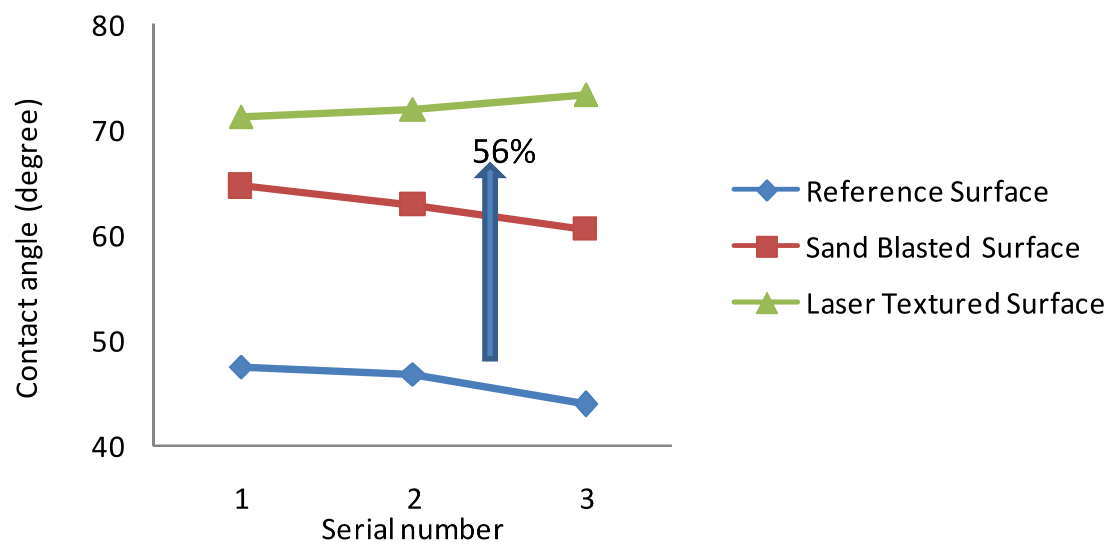
Contact Angles obtained in Textured Surfaces



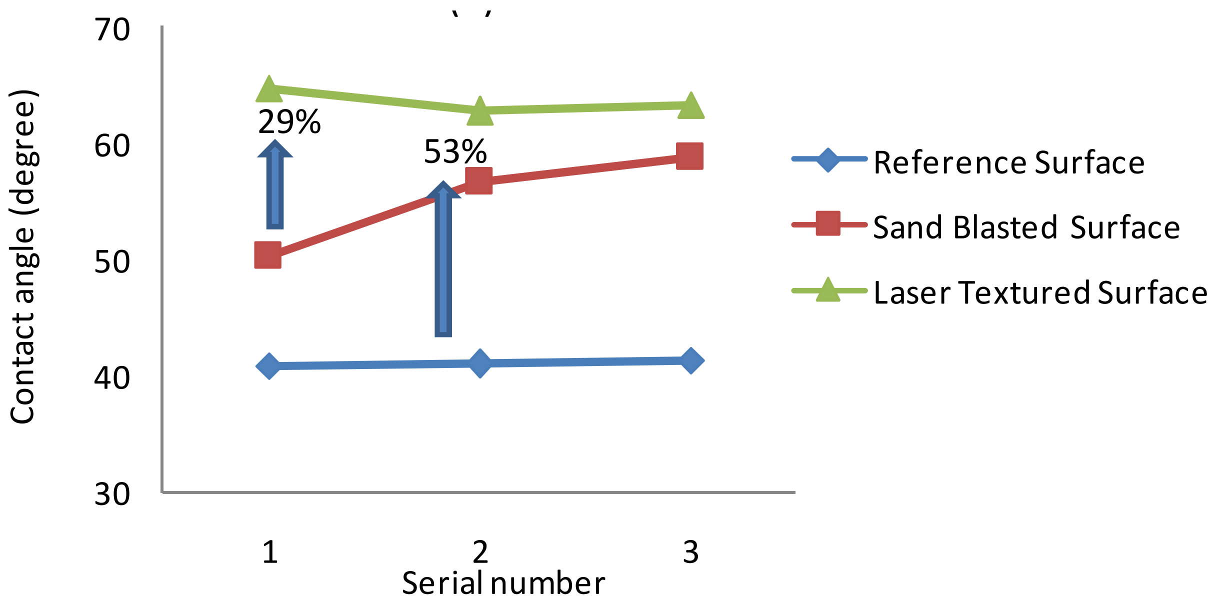
Comparative wettability test (Water)



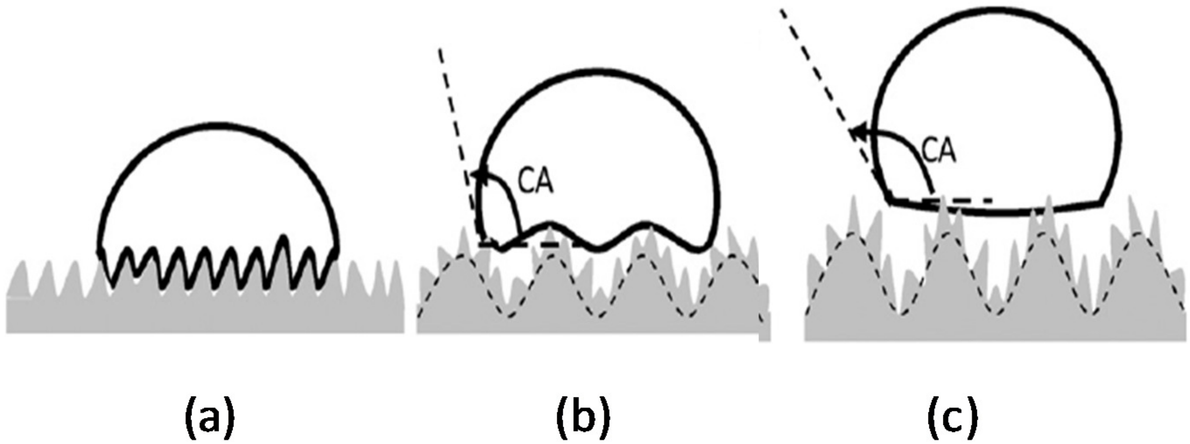
Comparative wettability test (ethylene glycol)



Comparative wettability test



Physical explanation



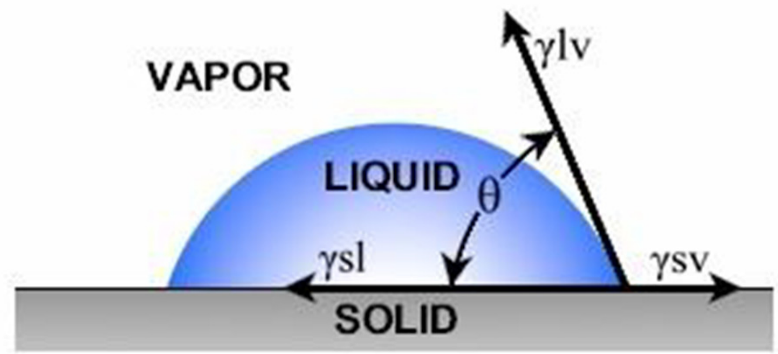
(a) Wenzel Model; (b) and(c) Cassie-Baxter Model

- Laser textures are not close to Wenzel's model and hence are not hydrophilic
- The air pockets trapped in the textures or the micro-scale roughness amplitudes prevent the drop from spreading over the rough surface
- A wetting condition closer to Cassie Baxter state of wetting is obtained

Contact angle

$$\cos\theta = \frac{\gamma_{SV} - \gamma_{SL}}{\gamma}$$

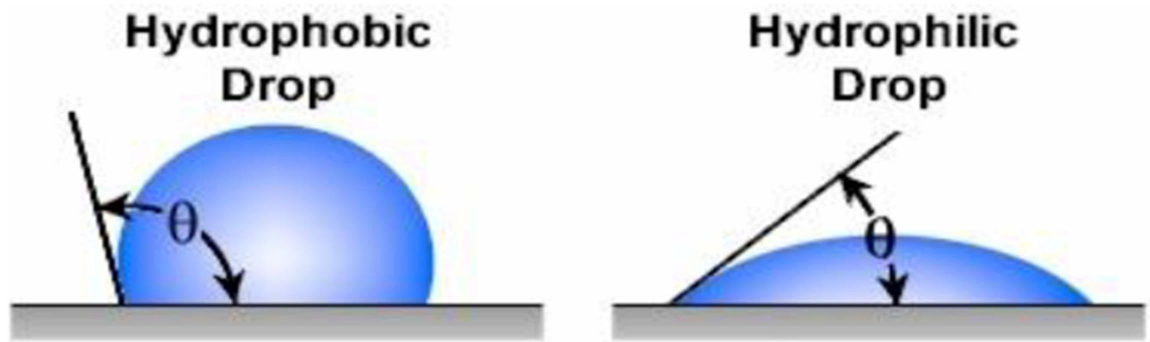
$$\gamma^{sv} = \gamma^{sl} + \gamma^{lv}\cos\theta$$



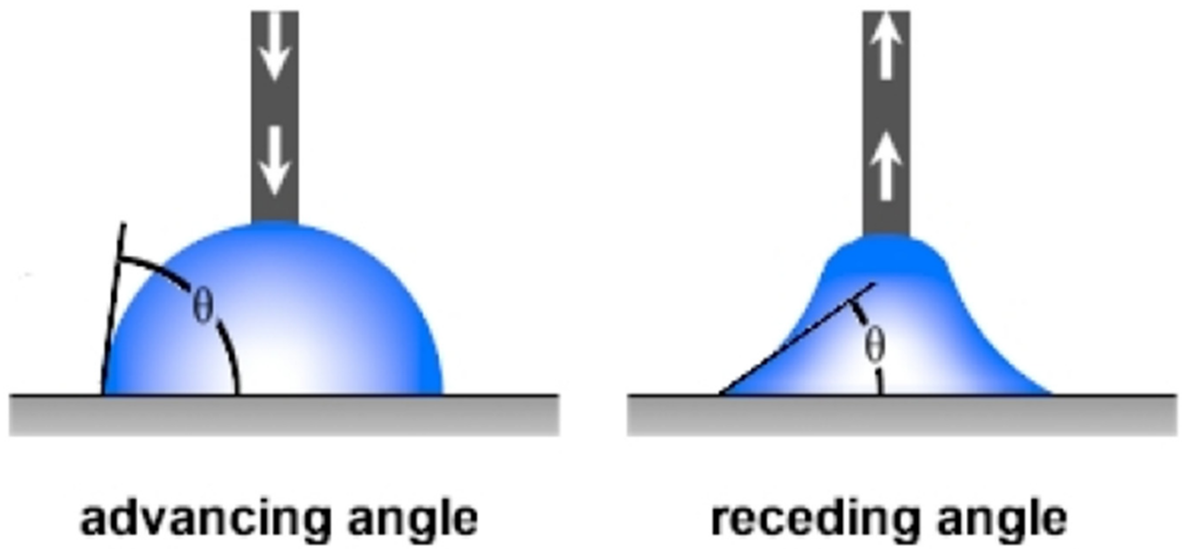
Where, γ_{SV}, γ_{SL} and γ are the surface tension of solid-vapour, solid-liquid and liquid-vapour interfaces respectively.

$0° < \theta < 90°$: Solid is wet by the liquid and the surface is termed as hydrophilic.

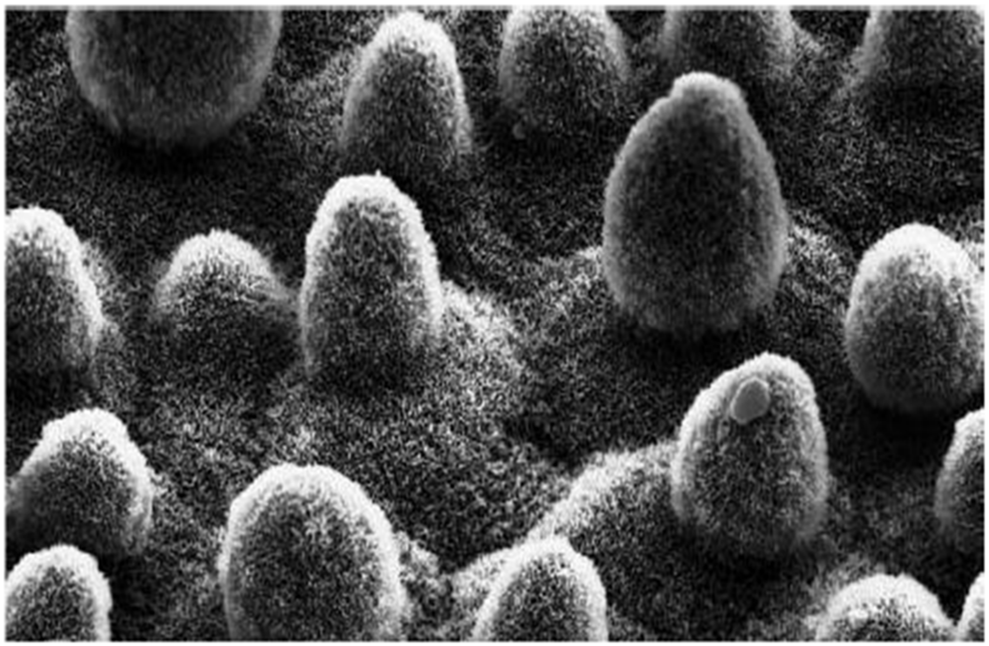
$90° < \theta < 180°$: Solid is not wet by liquid and surface is termed as hydrophobic

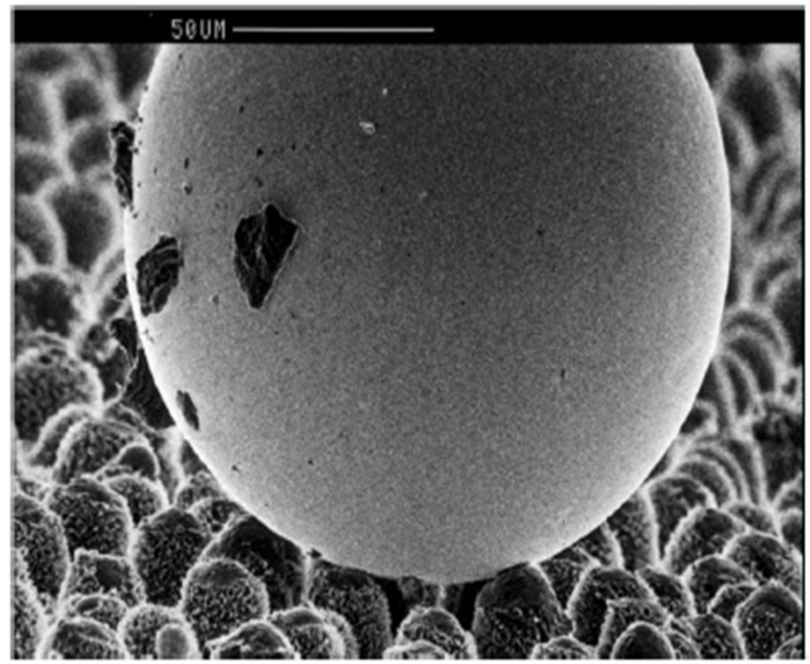


Advancing and Receding Contact angle



Lotus leaf effect

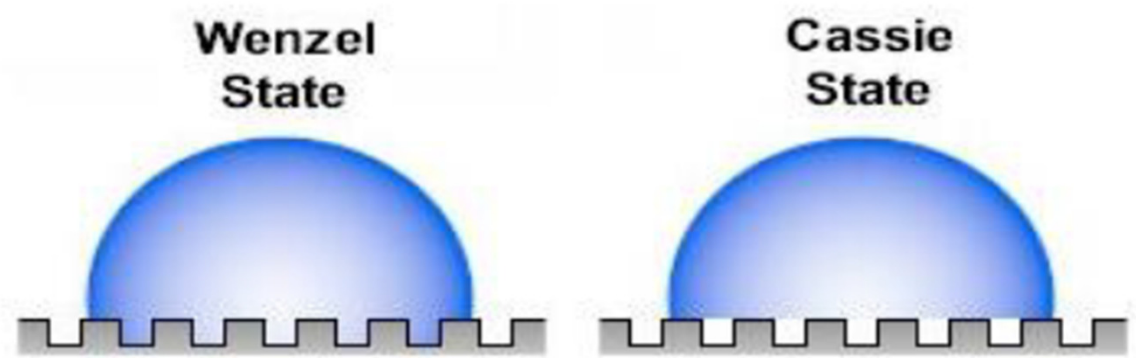




Self cleaning property as CA =160

Wenzel and Cassie Model:

When drop is put on the textured surface then there are two possibilities in which drop interact with the pattern on the surface.



Wenzel Equation:

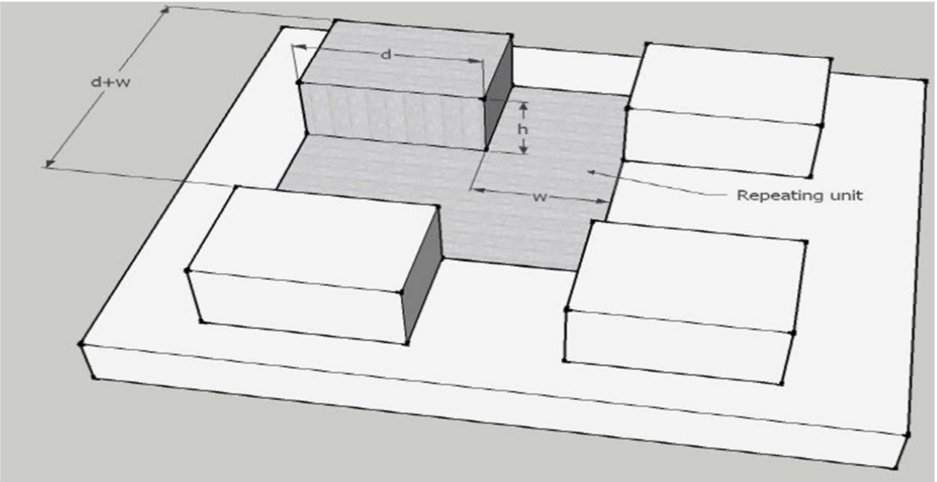
$$\cos\theta^* = r\cos\theta$$

$$r = \frac{Total\ suface\ area}{Total\ projected\ surface\ area} = \frac{Actual\ surface\ area}{Apparent\ surface\ area}$$

$$r = \frac{4dh + (d+w)^2}{(d+w)^2}$$

θ^* =Apparent Contact angle of a drop on the rough surface

r = roughness factor



Surface texture parameters to quantify roughness of surface

Cassie-Baxter Equation

$$\cos\theta^* = -1 + \phi(\cos\theta + 1) \qquad ....(1)$$

Where ø is the fraction of solid contacting the liquid

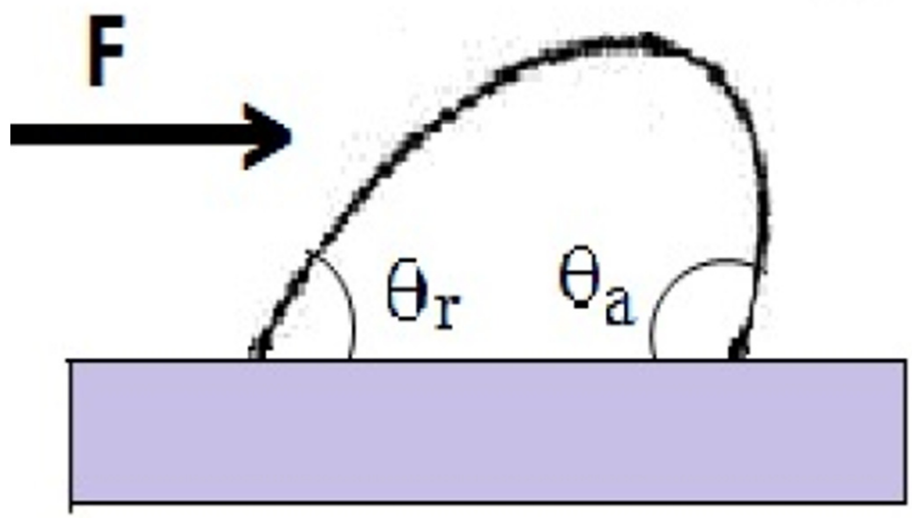
$$\phi = \frac{Total\ pillar\ top\ surface\ area}{Total\ projected\ surface\ area}$$

$$\phi = \frac{d^2}{(d+w)^2}$$

Equation (1) can also be written as: $\cos\theta^* = (1-\phi)\cos 180^o + \phi\cos\theta$

$\cos\theta^* =$(Fraction of liquid vapour interface)*(contact angle of liquid vapour interface) + (fraction of liquid solid interface)*(contact angle of liquid solid interface)

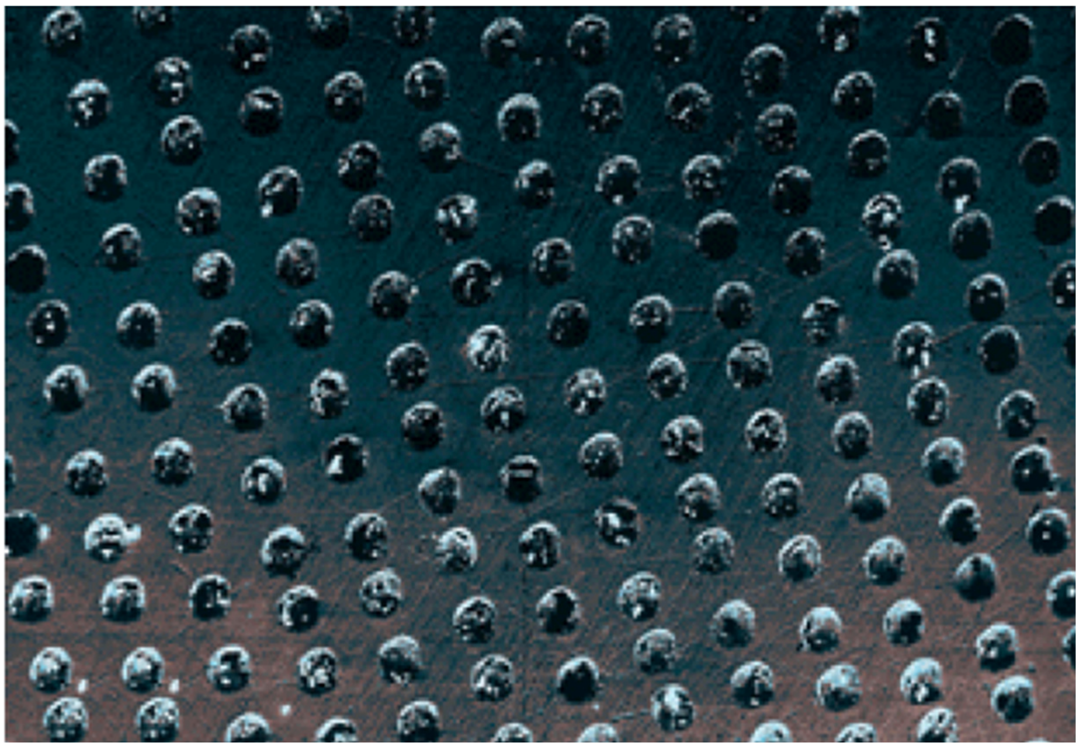
Force required to move the drop



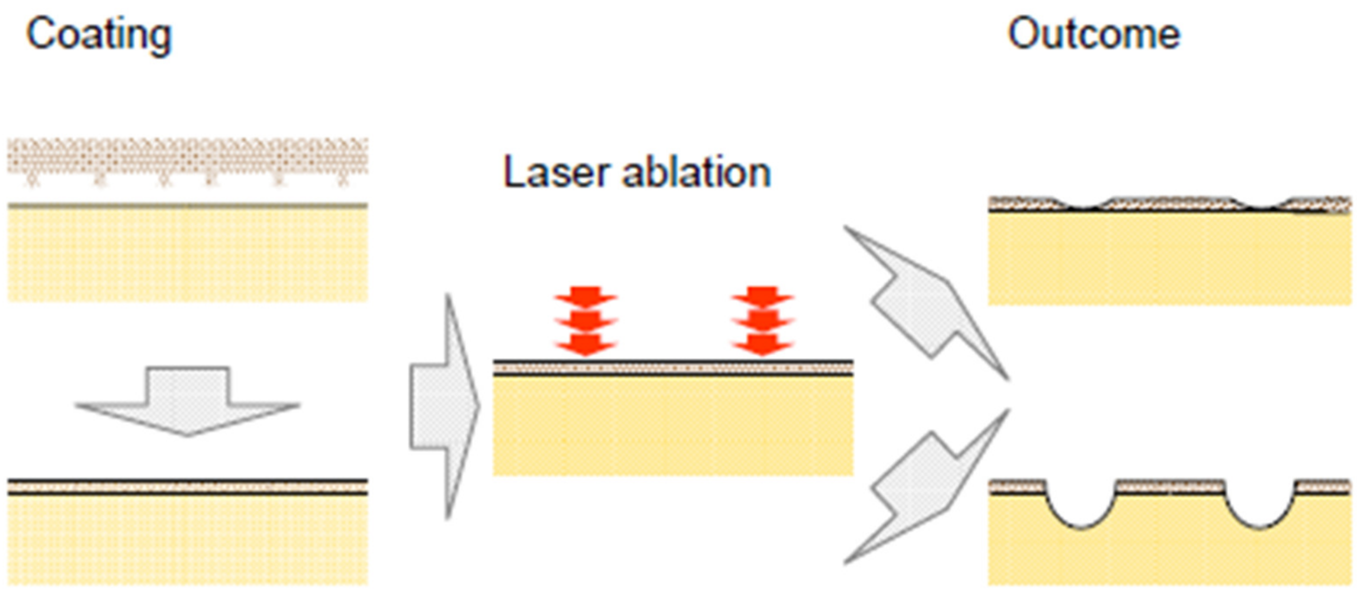
Force per unit length of perimeter when drop is just about to move is

$$F = \gamma(\cos\theta_r - \cos\theta_a)$$

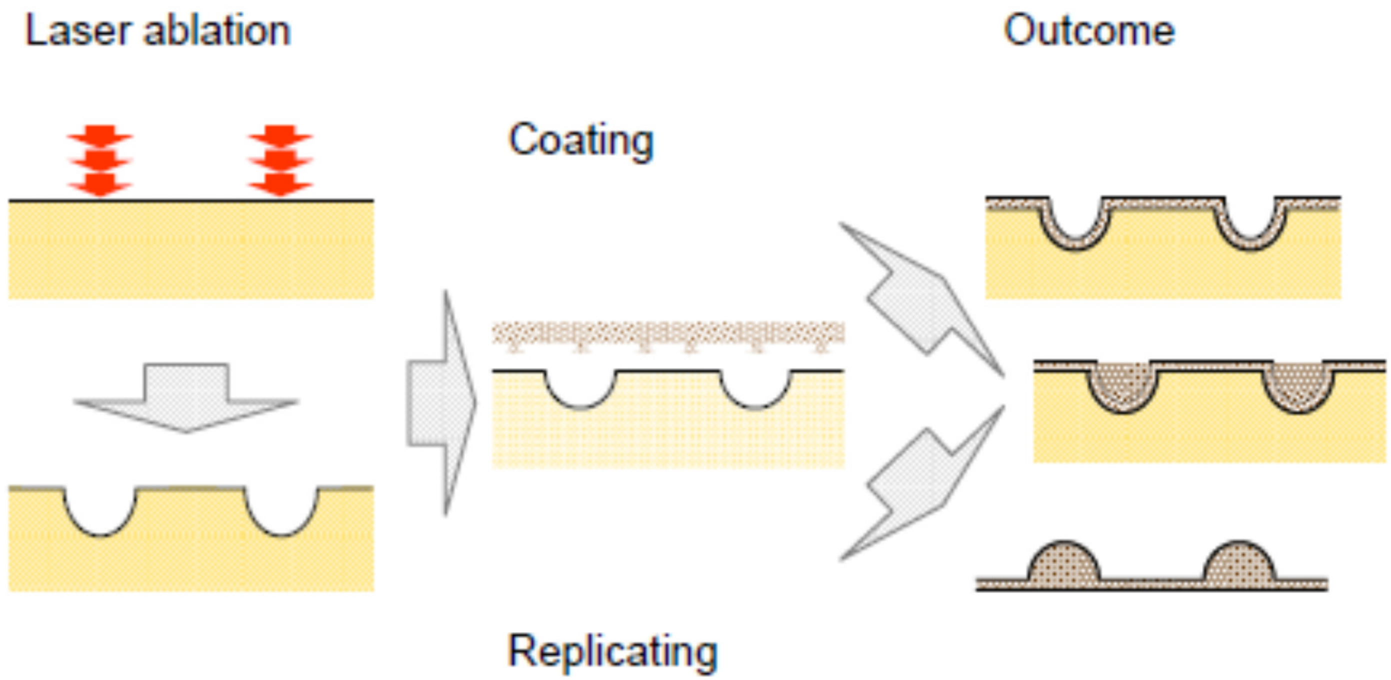
Tribological Applications-Regular Micro-structured surface in the form of dimples



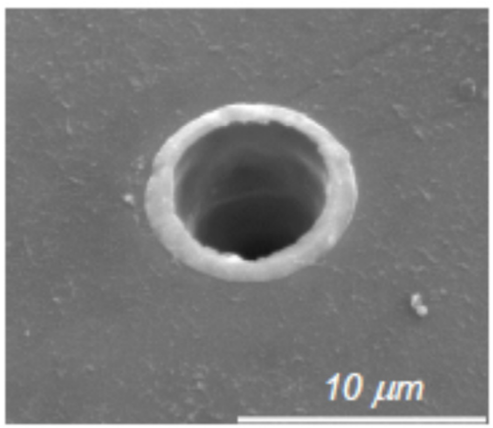
Direct Processing

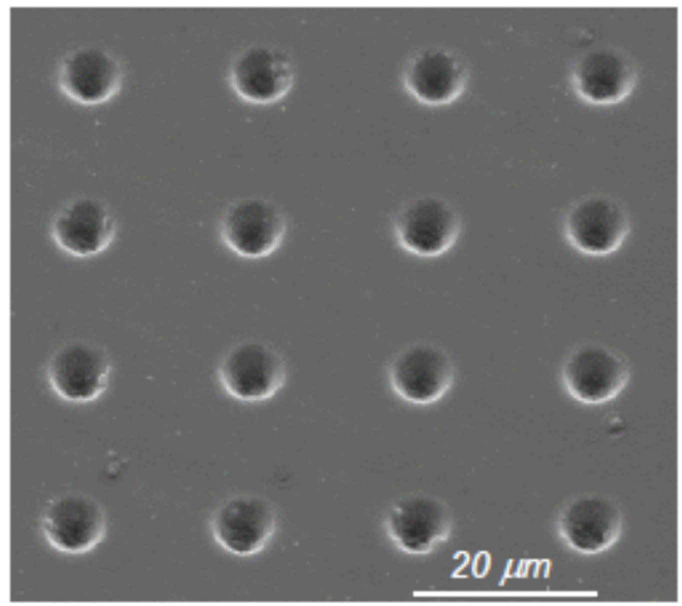


Indirect Processing

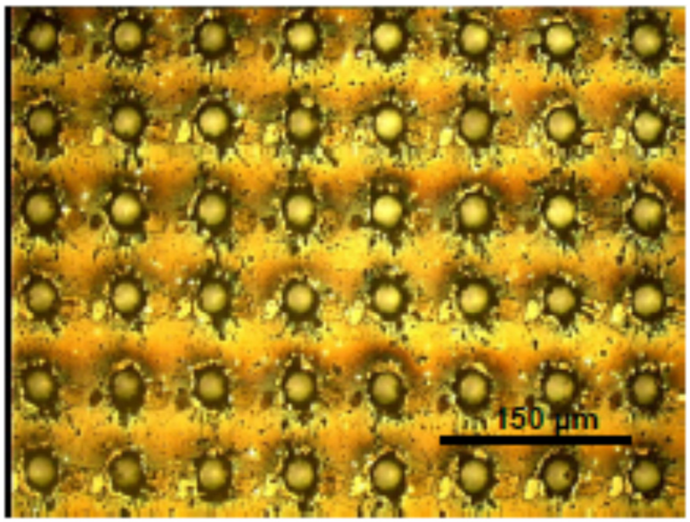


Laser ablated pores in SS



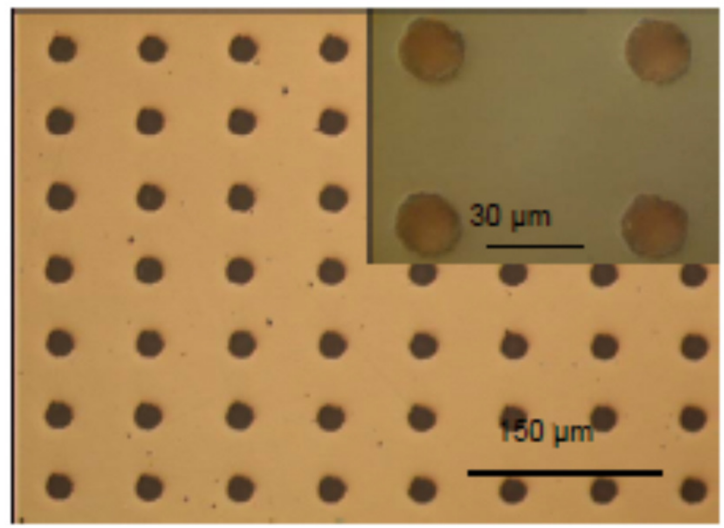


Indirect Laser Surface Texturing on 52100 Steel

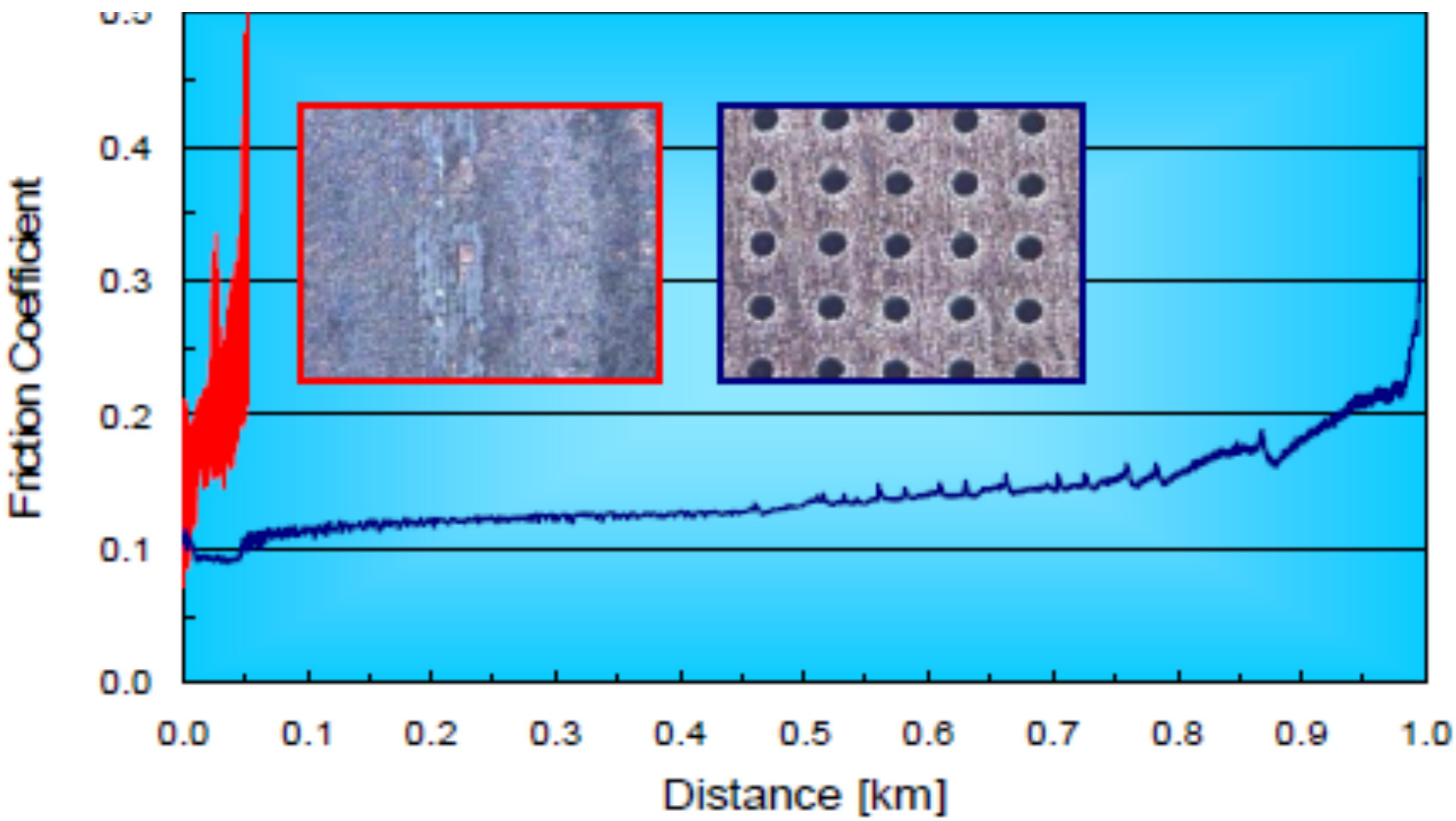


Laser patterned steel surface (not polished)

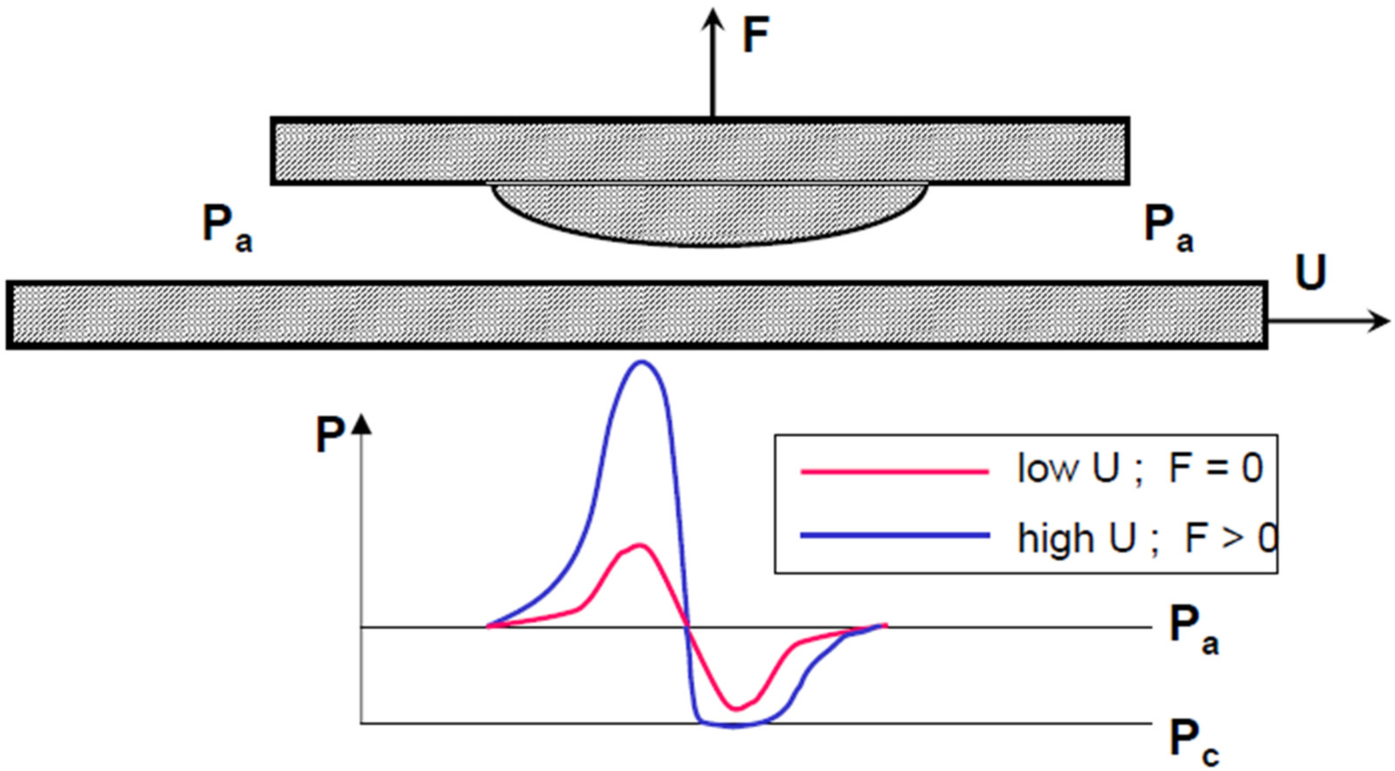
Laser patterned, polished, DLC coated surface: general view and detail



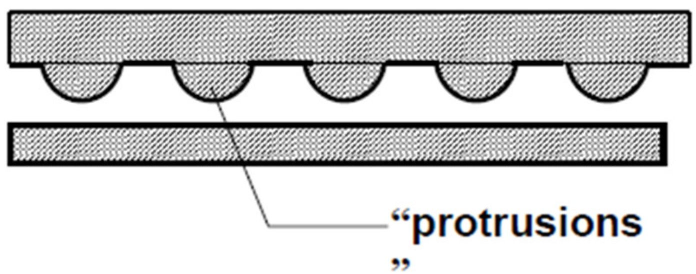
Frictional Response



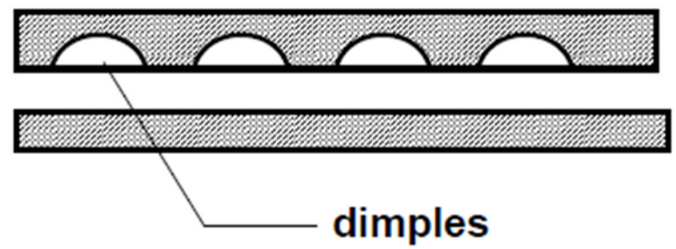
Hydrodynamic Pressure distribution over a single Protrusion



Why dimple?

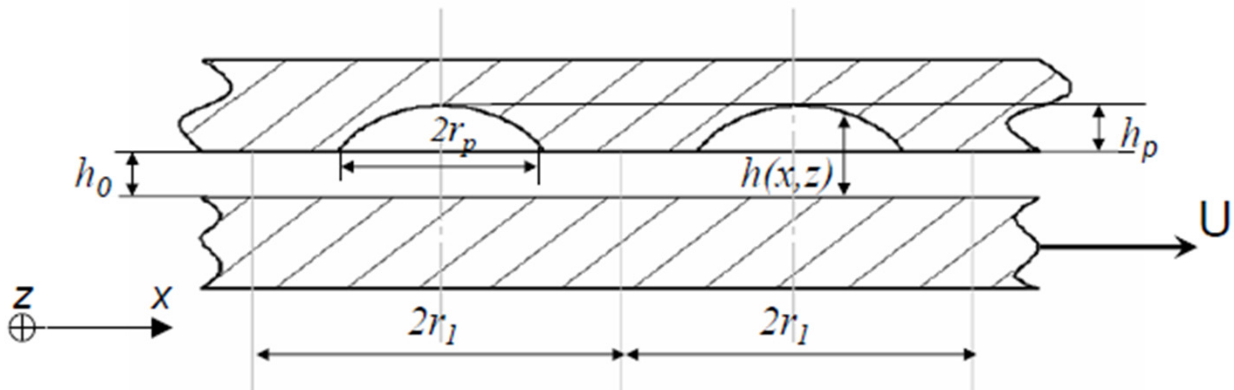


- complicated etching technology
- high wear
- high leakage (seals)



- simple & cheap laser technology
- lower wear
- low leakage/spacing

Film Thickness and Geometry of micro-dimples

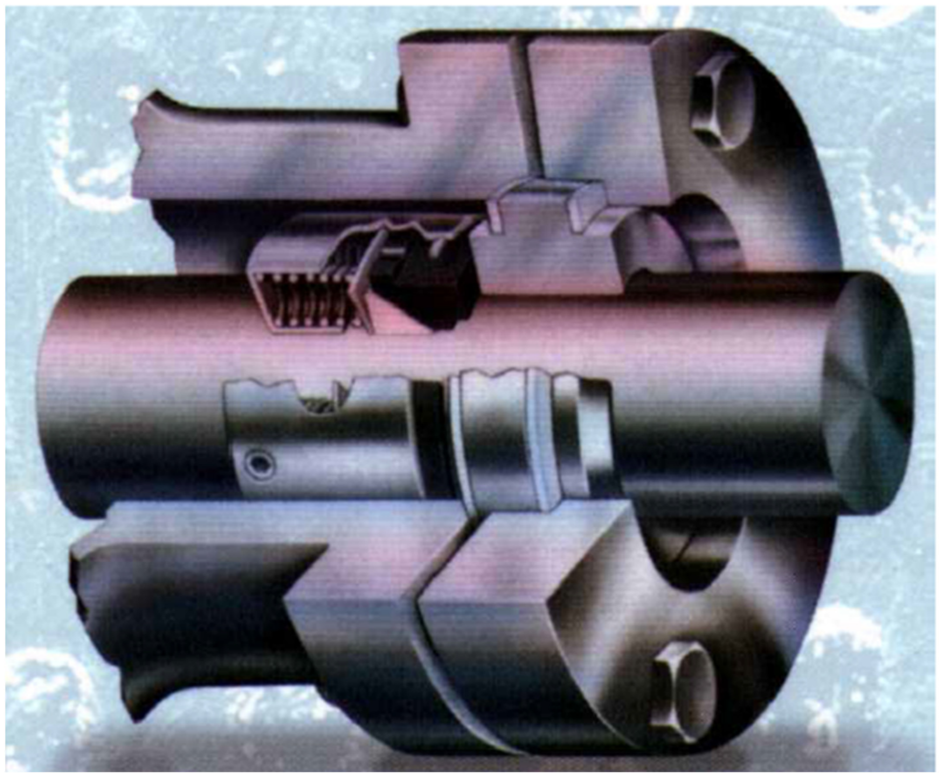


dimensionless minimum clearance : $\delta = h_0/(2r_p)$

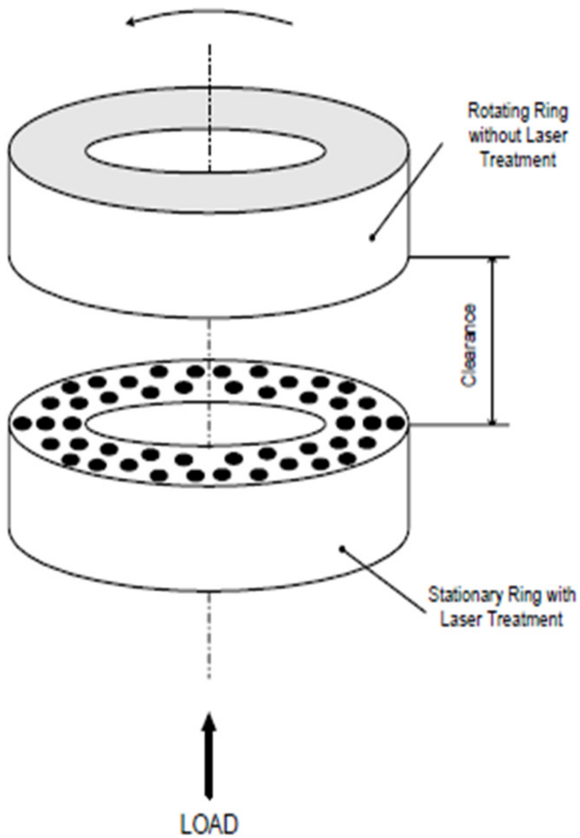
dimensionless local film thickness : $H = h/h_0 = H(\varepsilon, \delta)$

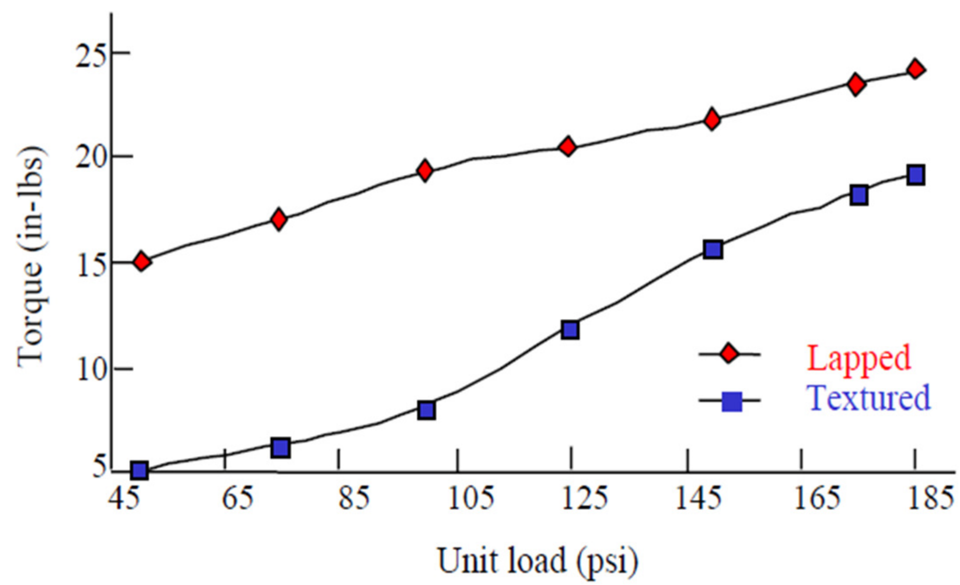
micro-dimple aspect ratio : $\varepsilon = h_p/(2r_p)$

Mechanical Face Seal



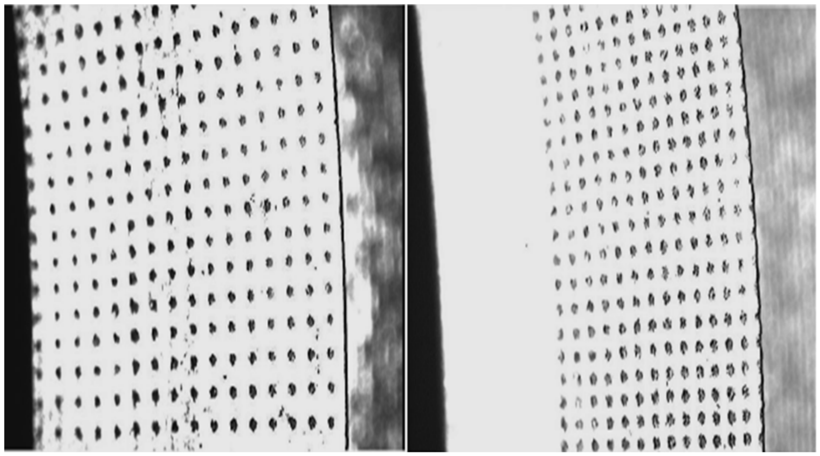
Ring on Ring scheme



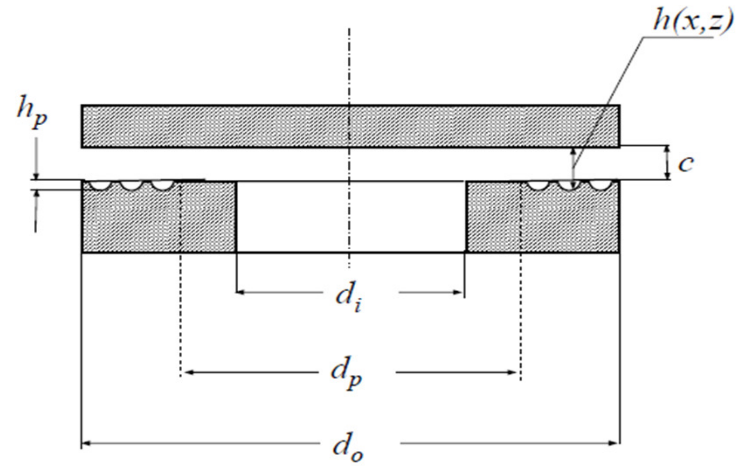


Friction Torque vs Face loading
For textured and non textured Seals

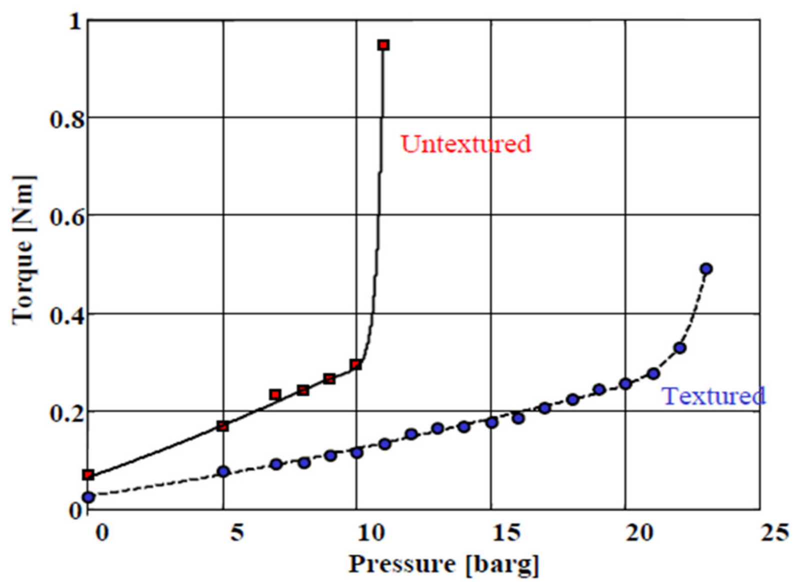
laser surface texturing of Mechanical Seal



Full and Partial LST on Seal

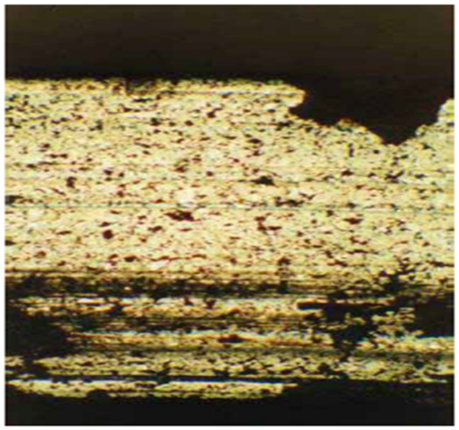


Schematic of Partial LST on Seal

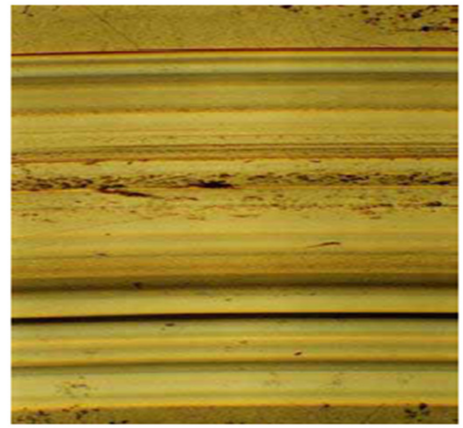


Friction Torque vs Sealed Pressure

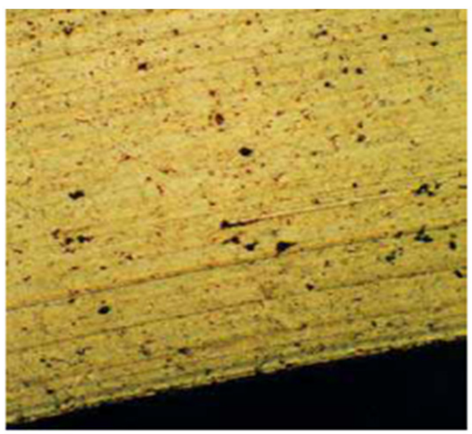
Field Test with water Pump



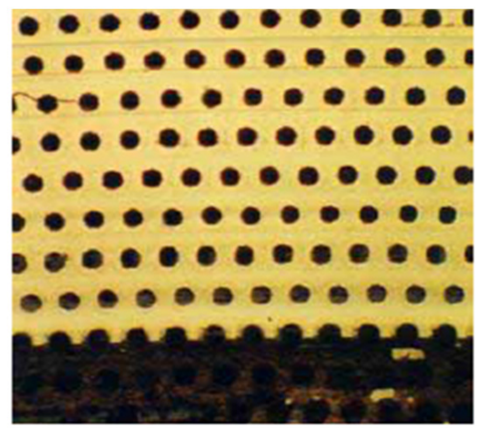
Carbon Ring - Standard Seal
After 400 Hours



WC Ring - Standard Seal
After 400 Hours

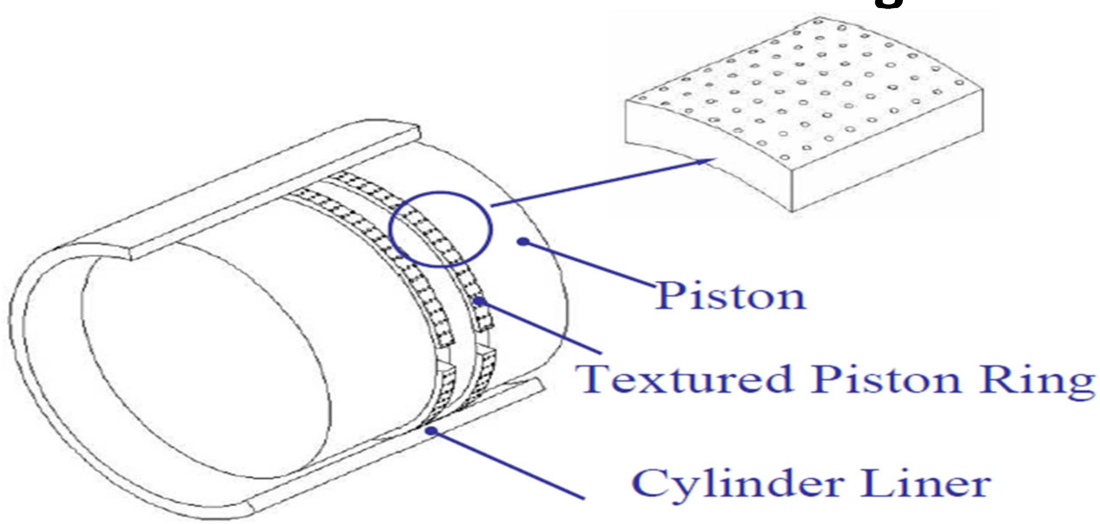


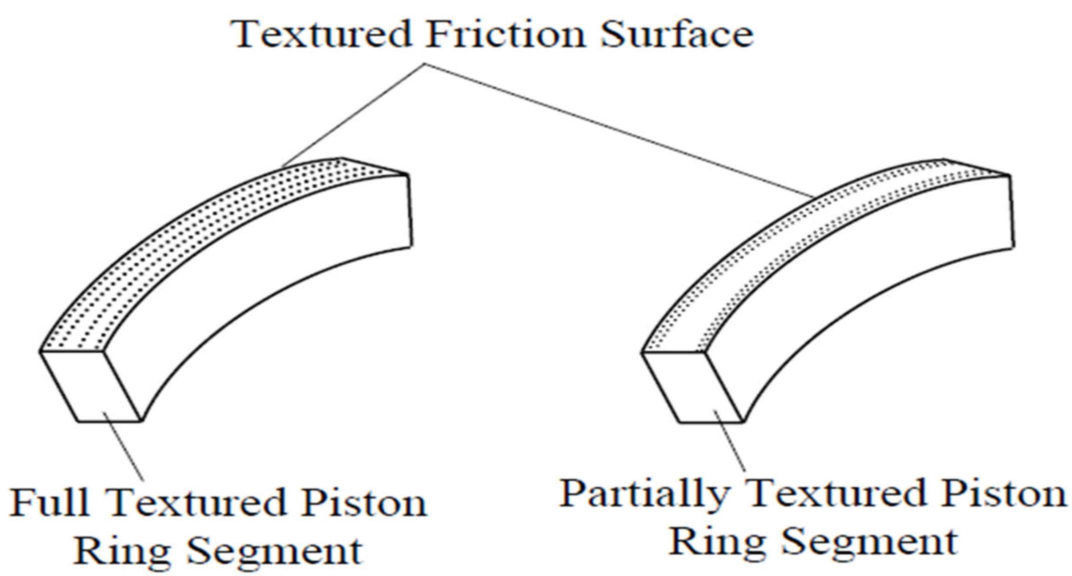
Carbon Ring - LST Seal
After 550 Hours



WC Ring - LST Seal
After 550 Hours

Laser Textured Piston Ring





Tape moving on LST Guide